INDUSTRIAL RESEARCH IN AMERICA[1]

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EVEN before the United States became a republic, some interest in industrial research was manifested.[2] This is evidenced in the preface to the initial volume of the *Transactions of the American Philosophical Society*, published in 1789, in which the aims of the society were presented. Among these were "making useful discoveries that would . . . promote the interest of the country." The earliest contribution to chemistry from this country, bearing the date September 10, 1768, appears in the *Transactions* of this society under the title "An Analysis of the Chalybeate Waters of Bristol in Pennsylvania," by John de Normandie.

The principal object of the Chemical Society of Philadelphia, which was founded in 1792 and was thus the first chemical society in the world, was to secure information relating to the minerals of the United States. A standing committee of five chemists was charged with the duty of analyzing any mineral which might be submitted to it, provided it was forwarded free of expense, with an account of the locality and situation in which it was found. The analyses were made without charge. In 1799, this society also gathered information relating to the manufacture of niter, acquainted the public with the uses of various minerals, and encouraged the manufacture of pottery. Evidence of the interest which was evinced at this time in ceramics may be found in an oration delivered by Felix Pascalis before the Chemical Society of Philadelphia in 1801. This savant said:

> Encourage and repeat mineralogical experiments on all kinds of alumine. The first who will successfully procure manufactured works of the kind and tolerably good earthen wares will deserve well of his country and be rewarded by the gifts of fortune.

Early Industrial Researchers

Among the earliest American scientists who became interested in the chemistry of manufacturing processes was James Woodhouse, professor

[1] Excerpts from a public address delivered at the Columbus, Ohio, meeting of the American Association for the Advancement of Science, December 29, 1915.

[2] It may be noted here that the first manufactures in colonial America—glass in 1610 and leather in 1630, both of which were established in Virginia—were chemical in nature.

of chemistry in the medical department of the University of Pennsylvania from 1795 to 1809. Woodhouse was the first to demonstrate the superiority of anthracite over bituminous coal "for intensity and regularity of heating power." Contemporaneous with this chemist were the following: Robert Hare, the inventor of the oxyhydrogen blowpipe (1802), who obtained calcium carbide, phosphorus, graphite and calcium by the aid of electricity, and is to be regarded as the earliest American experimenter in electrochemistry; Joseph Cloud, assay master at the Philadelphia Mint, who, in 1807, made an interesting research—the first in metallurgy in this country—on a native alloy of palladium and gold from Brazil; John Harrison, the first manufacturer of sulphuric acid in this country (1793), who was an ingenious industrialist and made a number of technical innovations in practise; and Gerard Troost, professor of chemistry at the University of Nashville, who established works for the production of alum at Cape Sable, Maryland, in 1814.

Considerable industrial research was carried on in the United States from 1820 to 1860. James Cutbush, professor of chemistry at West Point, made a number of valuable contributions to scientific pyrotechnics, but is chiefly remembered for his description, published in 1822, of the production of cyanogen by the action of nitric acid upon charcoal. Our first prominent industrial chemist, Samuel Guthrie, of Sackett's Harbor, N. Y., discovered chloroform, engaged in the manufacture of fulminating compounds, and devised a commercial process for the rapid conversion of potato starch into sugar (1832). Our first real metallurgical chemist, W. W. Mather, of Columbus, Ohio, made an elaborate research on the principles involved in the reduction of Mexican silver ores, in 1833. Lewis Feuchtwanger, who was well-known to the chemists of this period by his commercial establishment for the manufacture and sale of "rare" chemicals, devised, in 1837, an expeditious method for the manufacture of vinegar and later, in 1872, studied the process of glass-making. Then there was S. L. Dana, of Lowell, Mass., who was, for fifty years, the acknowledged authority in the United States on technical chemistry. After the completion of his medical studies in 1818, Dana soon devoted himself to manufacturing chemistry, holding the position of chemist to the Merrimac Print Works from 1833 to 1868; he invented the "American system" of bleaching in 1838, and was also an authority on manures and lead poisoning.

Among the other chemists of this period who busied themselves in the domain of industry were: J. C. Booth, of Philadelphia, Pa., noted for his work on beet sugar (1842), the production of gelatin (1842), the nickel ores of Pennsylvania (1856), and illuminating oils (1862), as well as for being the founder of an active firm of chemical consultants; John Dean of Boston, Mass., who investigated the value of different

kinds of vegetable foods in 1844; David Alter, of Freeport, Pa., the discoverer of spectroscopy, who began the manufacture of bromine in 1846 and later became a coal-oil technologist; Charles Lennig, an industrialist of Philadelphia, who was the first to manufacture bleaching powder in the United States (1847) and afterwards (1869) introduced the manufacture of hydrochloric acid by modern methods; L. C. Beck, professor of chemistry in Rutgers College, who made valuable observations respecting bleaching and disinfecting compounds and was an authority on bread-stuffs (1848); A. C. Twining, a chemical engineer of the fifties, who invented an ice machine; A. A. Hayes, of Brookline, Mass., a productive student of the Bessemer process (1852); C. M. Wetherill, who conducted researches on illuminating gas in 1854 and on the manufacture of vinegar in 1860; Benjamin Silliman, Jr., the author of technochemical classics on Pennsylvania petroleum (1855), California petroleum (1865 and 1867), and on the combustion of fuel (1860); E. N. Horsford, a researcher of great ability who worked out processes for preparing phosphoric acid (1856) and was active in establishing markets for this product; Henry Wurtz, of New York, who played an important part in the development of the manufacture of glycerol in 1858; and J. M. Ordway, of the Massachusetts Institute of Technology, who investigated the manufacture of sodium hydroxide in 1858 and the manufacture of water-glass from 1861 to 1865.

Industrial Research from 1860 to 1880

The late Joseph Wharton, of Philadelphia, deserves especial mention in the history of technology in America. After some preliminary experiments, Wharton erected at Bethlehem, Pa., in the year 1860, a spelter works of 16 Belgian furnaces, which produced over 3,700,000 pounds of zinc in 1862. The product was of excellent quality, and was made so cheaply as to afford a reliable profit and to plant the zinc industry firmly in the United States. Wharton first reduced silicate of zinc to metal on a large scale, successfully applied anthracite to the manufacture of spelter, and used American clays for making zinc retorts.

Many chemists rendered service to the advancement of industry during these two decades, and it is indeed difficult to designate the most prominent researchers. B. F. Craig, of the laboratory of the Army Medical Museum at Washington, D. C., worked in the field of explosives and, during the period 1861–1864, made a number of contributions to our knowledge of gunpowder. Frederick Hoffmann, of New York, was an authority on organic colors and medicinal chemicals. C. A. Goessmann, of the Massachusetts Agricultural College, contributed to the manufacture of salt (1863), the refining of sugar (1864), and the pro-

duction of beet sugar (1872). F. H. Storer, of Harvard University, made researches on the alloys of copper and zinc in 1864 and on petroleum in 1865.

While charged with responsible duties of administration, Charles F. Chandler, at present the honored dean of American chemists, was always productive in research. His early researches of technical importance were those on water for locomotives (1865), the water supply of New York (1868 and 1870), the purification of illuminating gas (1870), kerosene (1871), and the manufacture of condensed milk (1871). Another chemist who was called upon by the gas industry was Henry Wurtz, who made improvements in the methods of purifying water-gas (1867) and, jointly with Silliman (1869), elucidated the processes of manufacture.

The noteworthy researches of S. F. Peckham on asphalt and petroleum were carried on from 1867 to 1874. W. H. Chandler, who, with C. F. Chandler, edited the *American Chemist,* contributed to the purification of zinc containing iron (1869) and to the refining of iron (1870). J. B. Britton, chemist to the "Iron Masters' Laboratory," performed a great amount of technical work in ferrous metallurgy. S. Dana Hayes, state assayer of Massachusetts, studied the destructive distillation of naphtha in 1871 and was recognized as an expert in petroleum technology. Isidor Walz, of New York, was a textile expert. C. U. Shepard, Jr., of Charleston, N. C., an authority on fertilizers, investigated the effects of sulphur dioxide on vegetation in 1872. Henry Morton, of Stevens Institute, had occasion to conduct an extensive series of researches on petroleum from 1872 to 1874. J. P. Kimball, of Lehigh University, engaged in work in the manufacture of iron and steel, and found uses for emery in the iron industry (1873). The Nestor of the mining engineering profession, R. W. Raymond, investigated the calorific value of lignites in 1873. J. F. Babcock, of Boston, Mass., carried out researches which established him as an expert on wood preservation. T. M. Drown, professor of chemistry at Lafayette College, was the author of important papers on the blast furnace, the puddling and Bessemer processes, and the conditions of carbon in gray and white pig iron. H. M. Pierce was most active in the promotion of the interests of the wood distillation industry. C. E. Avery, of Boston, Mass., laid the foundation for the manufacture of lactic acid. Charles and Nelson Goodyear and A. G. Day, known for their inventions in connection with india rubber, may also be included among the industrial researchers of this period.

Industrial Research During the Last Three Decades

Sufficient has been presented to show that American scientists have, from the inception of the republic, been constantly engaged to a greater

or less degree in original investigations of the problems of manufacturing. Time will not permit the recounting of the many valuable contributions which have been made by the chemical profession during the most modern period of our industrial history, from 1880 to the present time. With your permission, I shall, however, refer to some of the most noteworthy researches.

The first electrochemical enterprise to be established at Niagara Falls was that of the present Aluminum Company of America for the manufacture of aluminum according to the process of Charles M. Hall. It was indeed remarkable that, after all the attention which had been given to aluminum, it remained for this young Oberlin graduate to devise the process by which 50,000 metric tons are now being produced annually in the United States and Canada. Hall possessed all the characteristics of an inventive genius.

Another distinguished electrochemist, H. Y. Castner, invented processes for the production of sodium and sodium hydroxide; while E. G. Acheson has discovered carborundum, artificial graphite, deflocculated graphite, and siloxicon. Both of these pioneers in modern electrochemical research succeeded in founding great manufacturing establishments, monuments to their rare investigative ability. Other chemists who have engaged with success in this field are the following: C. E. Acker, who devised a process for the manufacture of sodium hydroxide and bleaching powder which differs from the Castner process; W. T. Gibbs and S. P. Franchot, who invented a commercial process for the electrolytic production of potassium chlorate; T. L. Willson, who was the pioneer in the manufacture of calcium carbide and acetylene; Isaac Adams, the inventor of nickel-plating; and E. R. Taylor, who worked out a resourceful method for the commercial production of carbon disulphide.

Other brilliant inventors in the domain of chemical industry have been Herman Frasch, whose most valuable processes relate to the refining of petroleum and to the extraction of Louisiana sulphur; Waldron Shapleigh, who worked up methods for the extraction of the rare-earths from monazite; Thomas A. Edison, who, among many other things, first evolved a successful system of incandescent electric lighting; Charles Steffen, the deviser of the process for working over the mother liquors in beet-sugar manufacture; the Hyatts, who founded the great nitrocellulose industry; Arno Behr, who had such an active part in the development of the great corn-products industry; and J. B. F. Herreshoff, the eminent copper metallurgist and chemical engineer. These are a few of the researchers who have played a prominent part in the establishment of our industrial prosperity.

The Present Industrial Activity of the Chemist

If it is conceded that chemistry is the intelligence department of industry,[3] one may therefore conclude that the measure of the influence of the profession of the chemist upon the industrial development of our country constitutes *per se* an index of the value of research to manufacturing. I have pointed out in another place[4] that the measure of a country's appreciation of the value of chemistry in its material development and the extent to which it utilizes this science in its industries, generally measure quite accurately the industrial progress and prosperity of that country.

Early American Chemical Industries

Manufacture	First Manufacturer	Year	First Important Improvement	By Whom	Year
Sulphuric acid....	John Harrison, Philadelphia, Pa.	1793	Platinum still for concentrating.	John Harrison.	1814
Gunpowder	E. I. du Pont de Nemours, Wilmington, Del.	1802	Manufacture of potassium nitrate from sodium nitrate.	Du Pont Company.	1868
White lead.......	S. Wetherill & Son, Philadelphia, Pa.	1804	The use of cheaper material from Mo. and Ill.	———	1850
Pharmaceutical chemicals......	Rosengarten & Sons, Philadelphia, Pa.	1823	Production of ether and quinine, 1823; morphine, 1832; strychnine, 1834.	Rosengarten & Sons.	—
Varnish..........	P. B. Smith, New York, N. Y.	1828	Improvement of quality to create a foreign market.	P. B. Smith.	1836
Wood distillation .	James Ward, North Adams, Mass.	1830	Manufacture of acetate of lime and wood alcohol.	J. A. Emmons and A. S. Saxon.	1867
Nitric acid.......	Carter and Scattergood, Phila., Pa.	1834	Distillation apparatus.	Edward Hart.	1898
Hydrochloric acid.	Carter and Scattergood, Phila., Pa.	1834	Manufacture by modern methods.	Charles Lennig.	1869
Chlorine.........	Charles Lennig, Bridesburg, Pa. (bleaching powder).	1847	Commercial process for the electrolytic decomposition of sodium chloride.	E. A. LeSueur.	1893

[3] This statement should not give rise to an impression that the contention is that the industrialist relies *absolutely* upon the chemist. The technical demands made by modern manufacturers are extensive and exacting, and sole reliance upon the chemist would be oftentimes fatal to the realization of success. The aid of other industrial specialists must always be called in during the course of development.

[4] *Science*, 40 (1914), 871–81.

The public has been left to its own resources to determine the function of that industrial scout, the chemist. This condition has been briefly explained by one chemist:

> Our public work is obscured by impenetrable technical detail and our industrial achievements are cut off from public view by high factory walls.

A large percentage of the 10,000 chemists of the United States do labor under cover, yet these 10,000 men—about 25 per cent. of whom are engaged in industrial research, the others in control work—are actively occupied in manufactures which affect over 1,000,000 wage earners and produce over $5,000,000,000 worth of products. As Hesse[5] has quite convincingly demonstrated, in the case of thirty-one American industries, the chemists employed therein directly affect 24.6 per cent. of our manufacture values and 20.2 per cent. of our values added by manufacture. They are constantly engaged in the development of processes and in refining methods of control or of manufacture.

The Evaluation of Industrial Research

However, many industrialists are even now certain that research will not pay. Some regard their technology as a hereditary art. Some have favorable raw material conditions or a large demand for their products, and are therefore disinclined to invest a very small portion of their earnings in a reserve of knowledge. Others have prospered because of high tariff, notwithstanding short-sighted management. But most of our industries are built upon stronger foundations. It is plain that the use of natural laws offers a more stable basis upon which to erect a manufacture and a more uniform source of profit than any structure built upon artificial conditions created by legislation. Moreover, the quality and value of a product are based upon the application of correct principles in its conception, preparation and use, and the correct principles can only result from scientific research. Ample support to this contention is to be found in the manufacturing operations of to-day.[6]

The Future of Industrial Research in America

Prophecy is a double-edged tool with a peculiar facility for injuring the user, but the activity of the present leads one to predict that each succeeding year will bring us nearer to the state in which the research work of the country will be national in both scope and effort. The federal government and the states have done and are conducting research of immense value to agriculture, the foundation of industry; but the future will witness a more general application of this principle—an active national interest in industrial research, and this will serve as a healthy

[5] *J. Ind. Eng. Chem.*, 7 (1915), 294.

[6] On the contributions of the chemist to American industry, see Hamor, Sci. Mon., 1 (1915), 86; but especially Bacon, *Sci. Am. Suppl.*, 80 (1915), No. 2081, 334; and *Chem. News*, 112 (1915), 300.

subsidy for American manufactures. Research has enabled our industries to make rapid strides. The recognition of this fact has occasioned a recent awakening to an increased sense of appreciation of the need of greater facilities for insuring the scientific development and extension of industry and commerce and of promoting industrial research. Let us therefore proceed towards the adoption of this plan with unhalting step.

Our universities should make active preparation to assume their share of responsibility in this movement of national preparedness. There is too great a tendency in this country to regard intellectual men as a class apart from business men and especially from industrialists. It is a well-known fact that the German university has been one of the most anarchic of institutions, both the professorate and the students having had greater freedom than in the American universities; and at the present time Germany owes more to its universities as they have been conducted in the past than to its army as it is now organized.[7] In Germany there are captains of the intellectual group as well as of industry and of the military.

We must make ourselves self-sufficient. Some steps have been taken by the government, as, for example, in the formation of the Naval Advisory Board; but this is only a beginning. From the standpoint of real preparedness, the government should know exactly what her scientific and technical experts could best do for American industrial welfare and for their country in the event of war, and full particulars should be available regarding the research laboratories in the United States and the facilities thereof. American scientists are eager to render service to their country and to her industries.

A large industrial firm finds it advantageous to spend about 4 per cent. of its gross annual income on research, in providing for its future welfare and for keeping ahead of its competitors. On the same basis, if the United States expends $400,000,000 annually on its army and navy, it could, with profit, spend $16,000,000 a year on research. An equal sum, spent in the construction of a superdreadnaught, may be either an advantage or a loss; the research of carefully selected scientific men could be only an asset.

All this suggests the formation not only of a great national research laboratory, but also of a central bureau, in, say, the Federal Department of Labor, which would apply trained men to learn what American scientists are doing, their specific fields of investigation, and the equipment and research facilities of their laboratories, as well as to ascertain the problems of the various industries. This bureau could then put industrialists in touch with active university researchers, with the result that there would be an extension of both *useful* scientific investigation and manufacturing efficiency.

[7] See Cattell, *Pop. Sci. Mo.*, 87 (1915), 311.